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A new understanding on low permeability oilfield development

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From 1970s to 2000s, low permeability and extra-low permeability reservoirs in China could not be developed because of poor development philosophy and development technology. In those years, two billion tons of petroleum reserves of the low permeability and extra-low permeability reservoirs were undeveloped. Only very small amount of oil was produced from the low permeability reservoirs. Therefore, since 1990s, the authors have been focusing on a new oilfield development philosophy in low permeability and extra-low permeability reservoirs.

In the 1990s, the authors put forward a new field development philosophy that a large amount of oil existed in the low permeability reservoirs, but it could not be produce because formation pressure was too low; in other words, the pressure coefficient (ratio of the hydrostatic pressure to the original reservoir pressure at the testing point) of the reservoirs is less than 1. The reservoir fluid cannot flow into the wellbore under the original reservoir condition due to low reservoir pore pressure gradient. If one wishes to develop such tight reservoir, the well pattern of injectors and producers needs to be optimized, and the reservoir pressure needs to be increased by water injection and gas injection before such reservoir can be put into production. In addition, if the reservoir is very tight, it is difficult to inject water and gas, then hydraulic fracturing and acidizing has to be applied first to the injectors, before water injection and gas injection. This process may last for three to six months before the low permeability oilfields can be put into production. The reservoir pressure that can force fluid flow into wellbore is called "threshold pressure." If the fluid flow is a linear flow, the pressure is converted into a pressure of per unit length, called "threshold pressure gradient" (TPG).

The authors think that water injection with high pressure, preceded by stimulating reservoirs with acidizing and hydraulic fracturing in injectors and producers before oil production, will establish a displacement pressure system of the low permeability reservoirs, and allow the fluid flow to follow Darcy's Law. The authors presented a quantitative relationship among TPG, capillary pressure, fluid saturation and permeability. The TPG increases with the capillary pressure because the capillary pressure is a micro flow factor resulting from the TPG. In addtion, the results of experiment have shown that the TPG is inversely proportional to a power function of the original permeability: the bigger the permeability, the smaller the TPG. The stress sensitivity is a macro flow factor for the existence of the TPG. When permeability increases with decreasing effective stress, the TPG will reduce or disappear. The research points out that the TPG exists only when the reservoir-forming pressure of the low permeability reservoirs is too low, i.e., pressure coefficient being less than 1. If the low permeability reservoirs have high reservoir-forming pressure, and pressure coefficient is greater than 2, the TPG would not "exist" naturally. Successful development practice on the low-permeability tight reservoirs of Bakken play has proven the point in the United States. Based on the concept of the pressure coefficient, the authors derived an equation of the pressure gradient for the low permeability reservoirs by comparing the test values in the lab with the values of theoretical calculation.

It wasn't until 2000s that the oilfield development philosophy described above was used successfully in Changqing's low permeability and extra-low permeability reservoirs. It has become a major technology break-through in the low permeability and extra-low permeability reservoirs in China for now. Annual oil production from Changqing low permeability oilfield climbed from 2 million tons in 1997 to 20 million tons in 2012. By the end of 2012, oil production of 57 million tons in China came from the low permeability reservoirs, which accounts for 27.5% of the total oil production. In the future, China's oil production will rely more on the low permeability reservoirs.

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